CHAPTER 5

Hydrologic Engineering (HydEng)

General

Hydrologic Engineering (HydEng) is where hydrology, hydraulics, and levee data are entered for analysis. The data includes: water surface profiles, exceedance probability functions, stage-discharge functions, and levee features. Although optional, water surface profiles are recommended. The profiles are required when computing aggregated stage-damage uncertainty functions at damage reach index locations as specified under **Economics**. The profiles must be consistent with discharge (stage)-probability and stage-discharge (rating) functions required for each plan, analysis year, stream, and damage reach.

The discharge-exceedance probability uncertainty functions can be computed using either analytical or graphical procedures. Stage-exceedance probability uncertainty functions can also be computed and applied. The stage-discharge uncertainty function may be entered directly or the uncertainty specified for a stage and scaled for the other ordinates. Features for levee analysis are also defined under **HydEng**.

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- Water Surface Profiles
- Discharge (Stage)-Exceedance Probability Functions with Uncertainty
- Stage-Discharge Functions with Uncertainty
- Levee Features

Water Surface Profiles

Overview

A water surface profile is the stream water surface stage along a stream length associated with discharge values of a hypothetical or observed event. In HEC-FDA, a water surface profile data set must consist of eight flood events. They may be discharge or the stage based for each stream. Each profile set has stream stations, invert elevations, and discharge and stage values. The probabilities of each profile may be used to generate exceedance probability functions at index locations. Stream stationing must be consistent with the damage reach and structure location stationing. It is normally associated with water surface profile cross-sectional stations.

The default set of eight water surface profiles are for the .50-, .20-, .10-, .04-, .02-, .01-, .004-, and .002-exceedance probability flood events. The profile stream station and water surface stage values must increase or be equal from downstream to upstream. Discharge values of the water surface profile analyses are median values. You may change the probability designations under **Edit/Edit Probability Values**. The probability values are used for the graphical or synthetic discharge-exceedance probability functions if retrieved from water surface profile data. Figure 5.1 shows the water surface profile data entry screen. The profile data sets may be entered manually, copied from a previously developed stream profile set under **Use An Existing Profile**, or profiled copied from one plan to another under **Edit/Global Assignment Copy** or imported from HEC-RAS (USACE 1997) or HEC-2 (USACE 1991) results (See Appendix C).

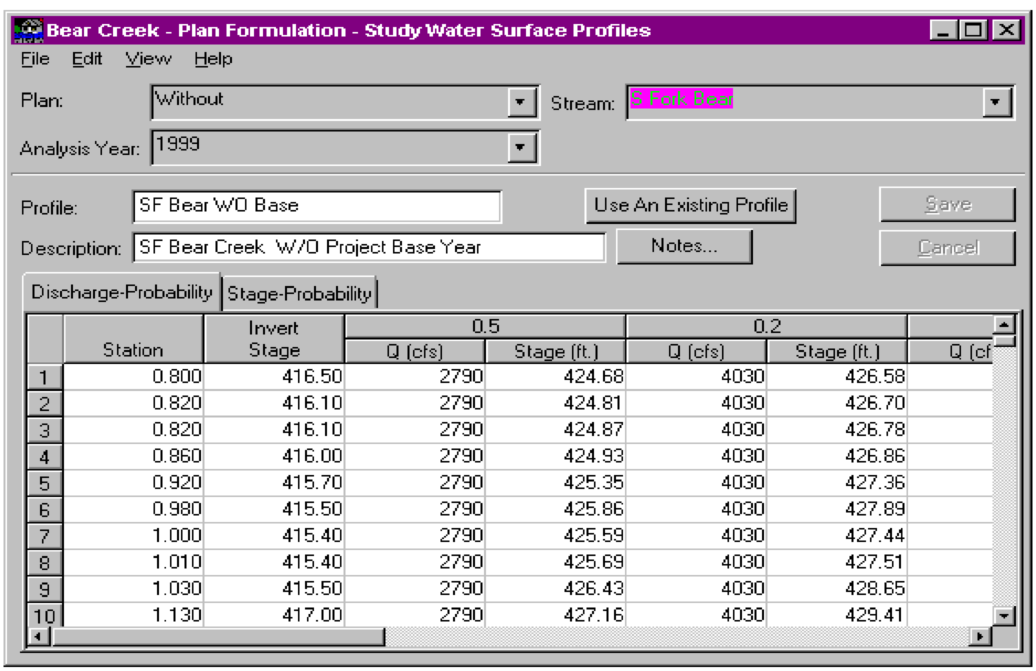


Figure 5.1 Water Surface Profile Screen

Water surface profiles may be used to develop without- and with-project condition discharge-probability (synthetic and graphical) functions and stage-discharge (rating) functions at an index location station within a damage reach. This ensures consistency of the data. Water surface profiles are also used under **Economics** to aggregate stage-damage functions with uncertainty for individual structures to the damage reach index location station.

Ponding or storage areas are defined using a stage-exceedance probability water surface profile. Unsteady flow modeling profiles are also normally stage-exceedance probability based.

Data for the water surface profiles may be imported from the water surface profile computation programs HEC River Analysis System package (HEC-RAS) and HEC-2 Water Surface Profiles program (HEC-2). (See the USACE, "HEC-RAS, River Analysis System User's Manual", 1997, and USACE, "HEC-2, Water Surface Profiles User's Manual", 1991, respectively.) Appendix C describes the importing process. Figure 5.2 shows the water surface profile import screen.

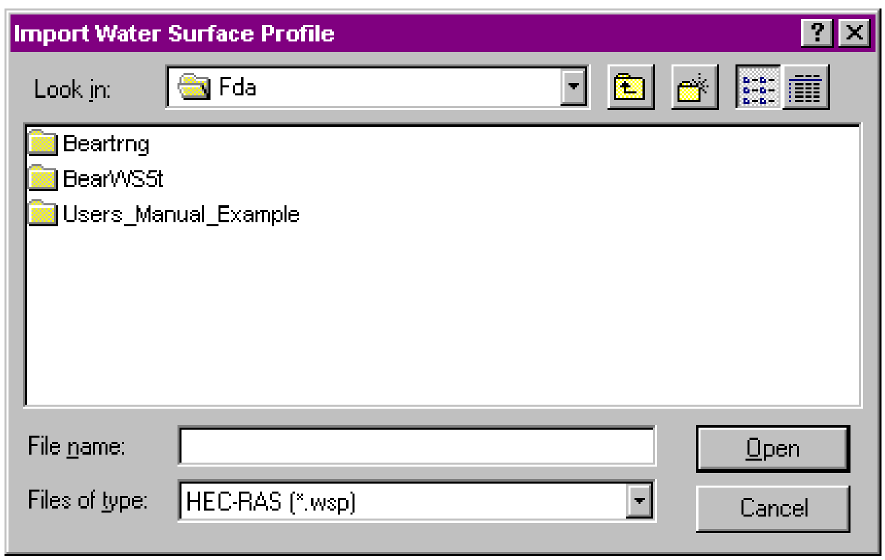


Figure 5.2 Water Surface Profile Import Screen

Hints:

- You may copy (assign) a previously defined water surface profile data set to this plan, analysis year, stream using **Use An Existing Profile**. For example: if the future condition profiles are the same as for the base year, you may copy the profiles of one plan to another using the **Assignment Copy** found under **HydEng/Water Surface Profiles/EDIT.**

The current water surface profile set may be viewed graphically or in tabular form. Select the View Menu and press “Water Surface Profile Stream Plot…” or “Water Surface Profile Report…”, respectively.

You can enter detailed notes about the water surface profile set by selecting **Notes**. By default, contains the file name of imported data.

You may review **Water Surface Profile Assignments** under the **VIEW Menu**. Table 5.1 is an example of an assignment table for water surface profiles.

Table 5.1
Des Plaines River
Water Surface Profiles Assignments

Plan Name	Year	Stream Name	Water Surface Profile Name	Water Surface Profile Description
Without	1999	Des Plaines R	WO Proj-Base Yr	W/O Project Base Yr Sta 17.84 to 10.3
	2010	Des Plaines R	WO Proj-Future	W/O Project Future YR (2010)
Plan 1	1999	Des Plaines R	****	****
	2010	Des Plaines R	****	****

* Assignment made but some required data is missing.
**** No Assignment

Menu Items for the Water Surface Profiles Screen

Please refer to the Menu Items section in Chapter 3.

Data Entry Variables for Water Surface Profiles

Plan Name: Name previously defined under **Config.**

Analysis Year: Name previously defined under **Config.**

Stream Name: Name previously defined under **Config.**

Water Surface Profile Name: Name for the defined water surface profile set, which is used in the hydrologic engineering and economic analyses. This name will appear on certain reports and plots. A new water surface profile set can be added, copied, updated, or deleted. The maximum length of the name is 16 characters.

Water Surface Profile Description: Short description of the defined water surface profile set will appear on certain reports and plots. The maximum length of the name is 64 characters.

Water Surface Profile Type: There are two types of water surface profiles. **Discharge-Probability** is where the profiles are based on discharge values. The discharge and the associated stage values are required for each station and exceedance probability flood event. **Stage-probability** is where the water surface profiles are based on stage values only. The stage values are required for each station and exceedance probability flood event.

Station: Study adopted stations along the stream normally denoted as miles (kilometers) above the mouth of the stream. Must be consistent between damage reach boundaries, damage reach index location, water surface profiles, and structure location. The range of allowable values is from -999,999.99 to 999,999.99.

Invert Stage: Stage associated with zero discharge or the bottom of a channel. The range of allowable values if from -300.00 to 30,000.00.

Discharge (Q): The volume of water passing a specific point for a given time interval. For example, 2,000 cubic feet per second or 1,000 cubic meters per second. The range of allowable values is from 0 to 9,999,999.

Stage: The vertical distance is feet (meters) above or below a local or national datum (N.G.V.D. for elevations). The range of allowable values is from -300.00 to 30,000.00.

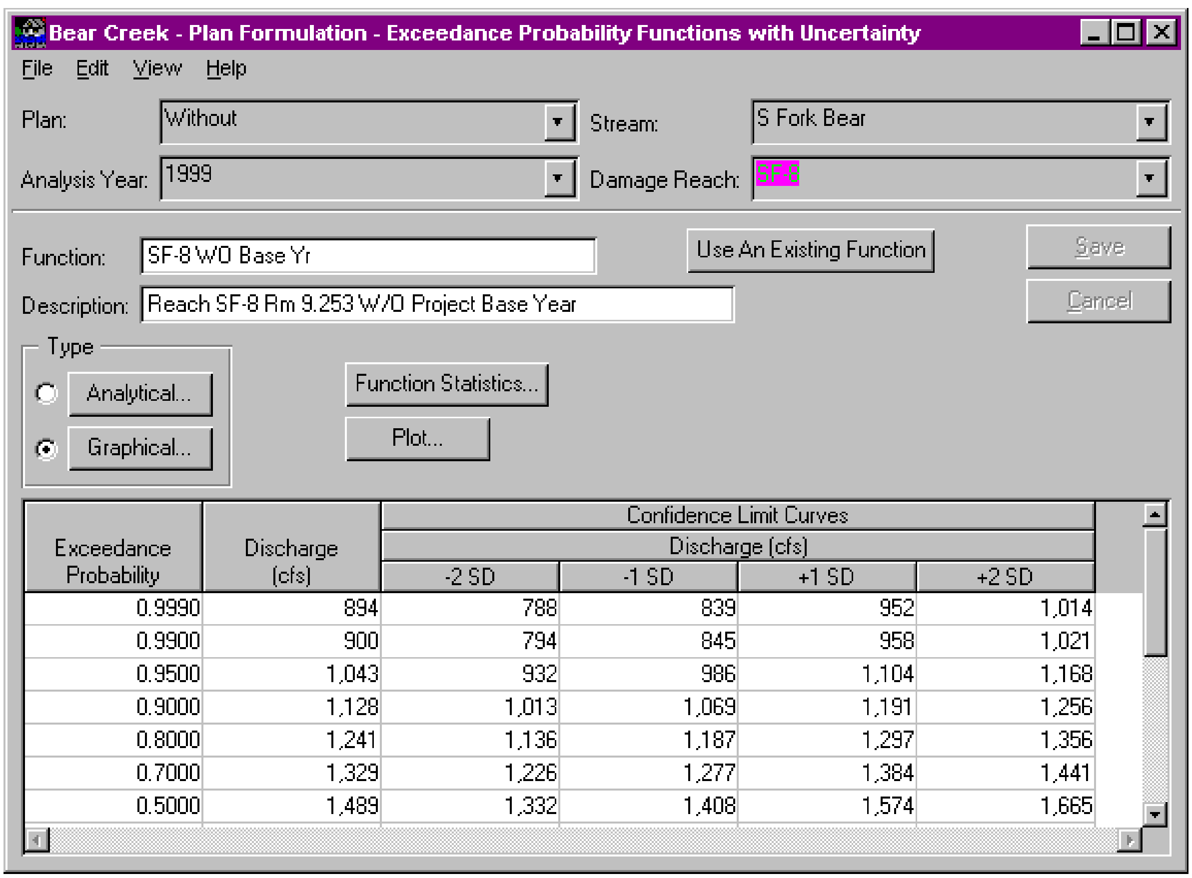
Exceedance Probability Functions with Uncertainty

Overview

Economics and performance analyses require an exceedance probability function to be defined (assigned) for each Plan, Analysis Year, Stream, and Damage Reach. They are specified on the main data entry screen as shown in Figure 5.3. The same functions may be used for several reaches, plans, and analysis years but not different streams. You may retrieve a synthetic or graphical exceedance probability function from the water surface profile enter the data manually, or **Use An Existing Function** that was previously developed. You may also copy the exceedance probabilities of one plan to another plan using the **Global Assignment Copy** found under **HydEng/Exceedance Probability Functions** with **Uncertainty/Edit**. An exceedance probability (or frequency) function can be either analytical (discharge-probability) or graphical (discharge- or stage-probability).

Analytical-Exceedance Probability Method

If the discharge-exceedance probability function can be fitted by a Log Pearson Type III distribution, the "Analytical" option should be used. Analytical methods often apply for unregulated discharge-probability functions derived from streamgaged data or modeling. There are two methods of defining analytical discharge-probability functions. The default method is to enter the Log Pearson Type III statistics which are the mean, standard deviation, skew, and equivalent record length. The other method is to enter the discharges for the .50, .10, and .01 exceedance probability events to compute synthetic statistics. For analytical methods, the median discharge-exceedance probability functions are used. See ER 1110-2-1450, EM 1110-2-1415, EM 1110-2-1619, and Interagency Advisory Committee on Water Data, "Guidance for Determining Flood Flow Frequency, Bulletin 17B," U.S. Department of Interior, U.S. Geological Survey, Office of Water Data Coordination, Reston, VA.



Exceedance Probability	Discharge (cfs)	Confidence Limit Curves Discharge (cfs) -2 SD	-1 SD	+1 SD	+2 SD
0.9990	894	788	839	952	1,014
0.9900	900	794	845	958	1,021
0.9500	1,043	932	986	1,104	1,168
0.9000	1,128	1,013	1,069	1,191	1,256
0.8000	1,241	1,136	1,187	1,297	1,356
0.7000	1,329	1,226	1,277	1,384	1,441
0.5000	1,489	1,332	1,408	1,574	1,665

Figure 5.3 Exceedance Probability Function Screen

Enter Analytical Exceedance Probability Function

Analytical Method - Under analytical, you may choose to define the discharge-exceedance probability function data by Log Pearson III Statistics, Synthetic statistics, or the Transform method as shown in Figure 5.4.

Log Pearson III Statistics data entry screen is shown in Figure 5.4. This uses Bulletin 17B procedures for computing the function and uncertainty (confidence limits) from the mean, standard deviation, skew, and equivalent record length. You may tabulate or plot the representative discharge-exceedance probability function. An example tabulation on an analytical exceedance probability table is shown in Figure 5.5. Figure 5.6 shows a plot.

Synthetic Statistics data entry screen is shown in Figure 5.7. This uses Bulletin 17B procedures for computing the function and uncertainty by defining the function based on the .50, .10, and .01 exceedance probability discharge values and equivalent record length. You may tabulate or plot the representative discharge-exceedance probability function.

Menu Items for Analytical Exceedance Probability Functions

Please refer to the Menu Items section in Chapter 3.

Hint:

- You may retrieve the damage reach index location synthetic probability function .50-, .10-, and .01 values from the appropriate water surface profile data set under **EDIT/Synthetic from WSP.**

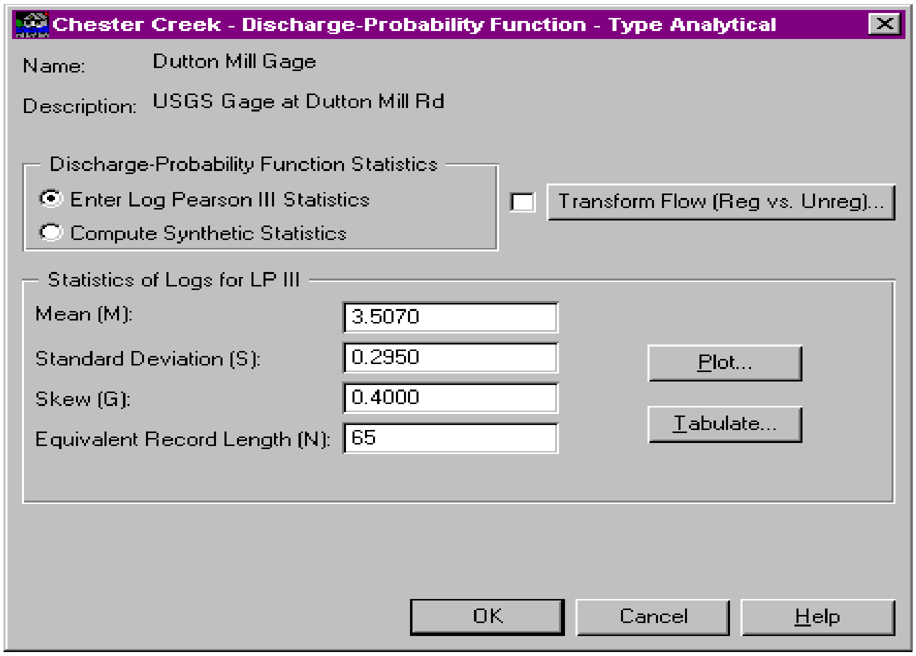
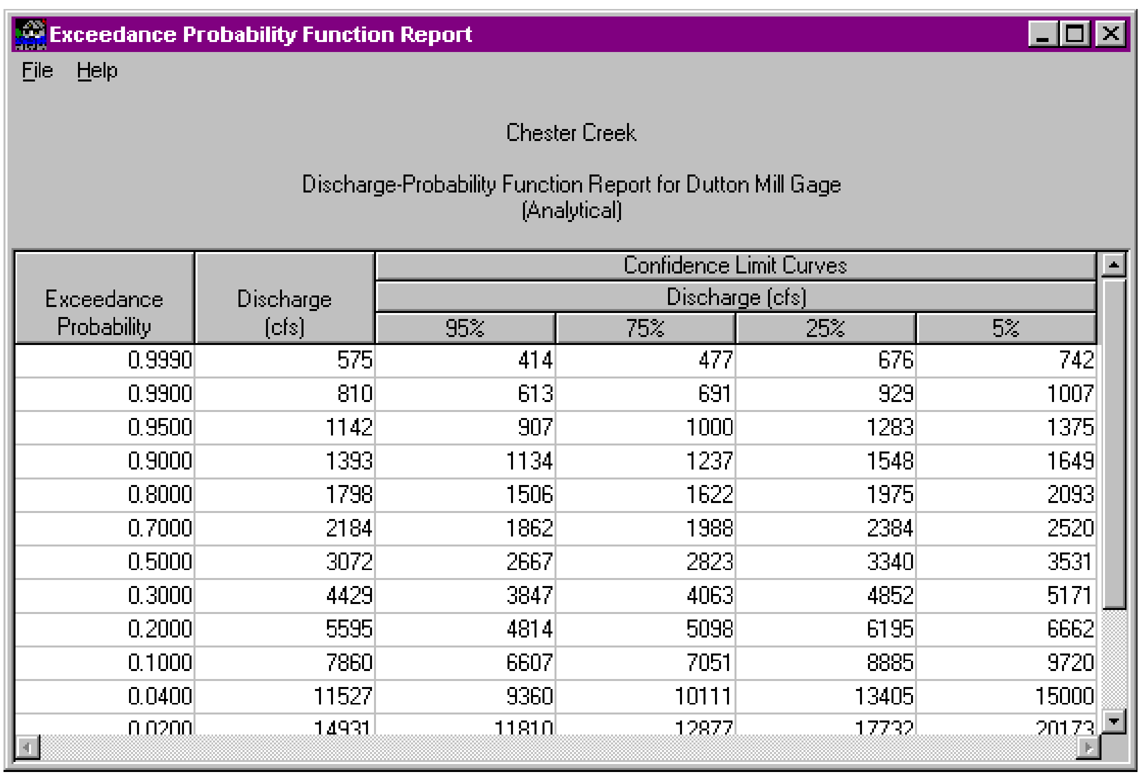


Figure 5.4 Analytical Discharge-Exceedance Probability Function Data Entry Screen



Exceedance Probability	Discharge (cfs)	Confidence Limit Curves Discharge (cfs)			
		95%	75%	25%	5%
0.9990	575	414	477	676	742
0.9900	810	613	691	929	1007
0.9500	1142	907	1000	1283	1375
0.9000	1393	1134	1237	1548	1649
0.8000	1798	1506	1622	1975	2093
0.7000	2184	1862	1988	2384	2520
0.5000	3072	2667	2823	3340	3531
0.3000	4429	3847	4063	4852	5171
0.2000	5595	4814	5098	6195	6662
0.1000	7860	6607	7051	8885	9720
0.0400	11527	9360	10111	13405	15000
0.0200	14931	11810	12877	17732	20173

Figure 5.5 Analytical Discharge Exceedance Probability Table

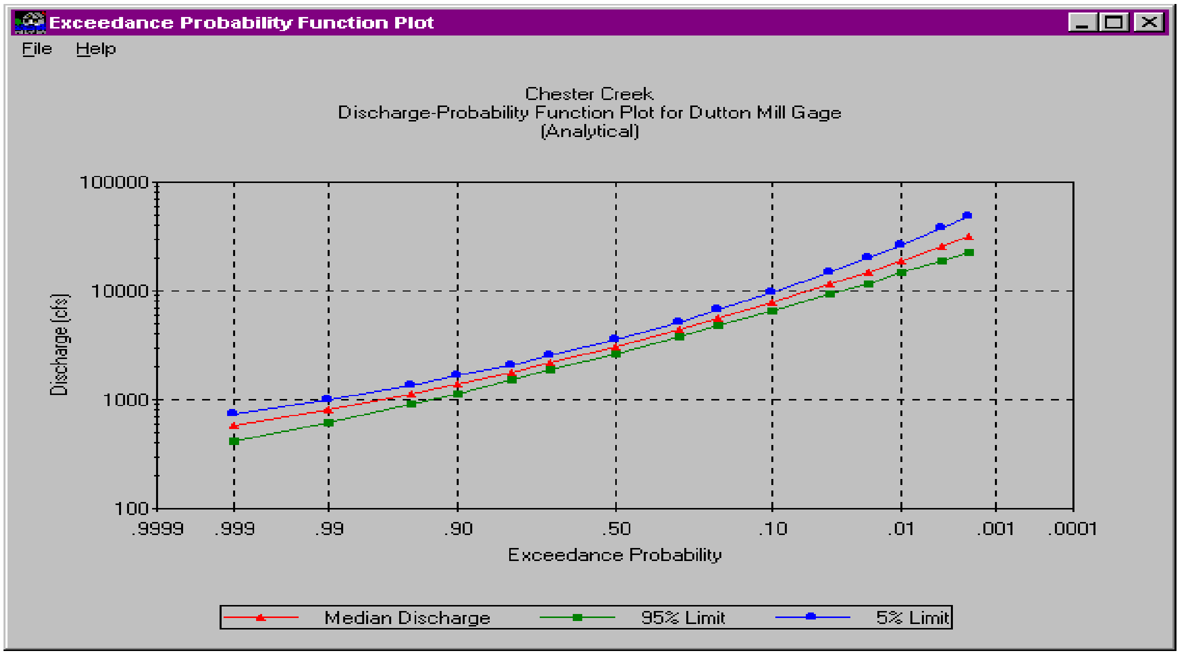


Figure 5.6 Analytical Discharge-Exceedance Probability Plot

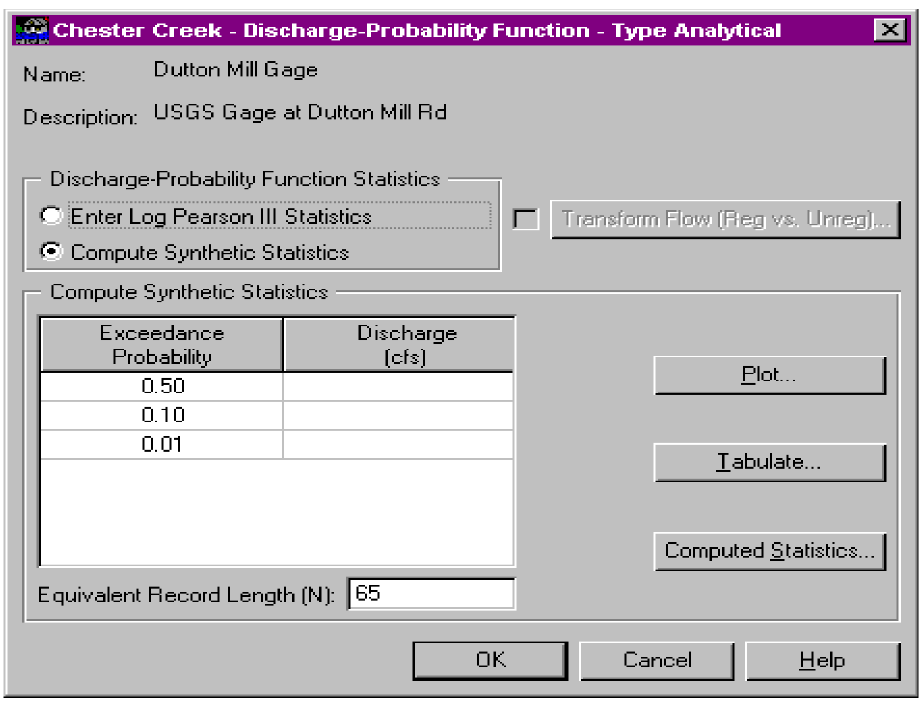


Figure 5.7 Analytical (Synthetic) Discharge-Exceedance Probability Function Screen

Graphical Exceedance Probability Method

If the function does not fit the Log Person Type III distribution, the graphical approach should be used. The Graphical approach is typically applicable for regulated flows, stage-exceedance probabilities (often storage based or UNET (Barkau, 1992) unsteady flow modeling results), and partial duration functions. The graphical method uses an approach termed order statistics. For the graphical method, see ETL 1110-2-537, or "Uncertainty, A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis" by Morgan and Henron. Figure 5.8 shows the Graphical Exceedance Probability function data entry screen.

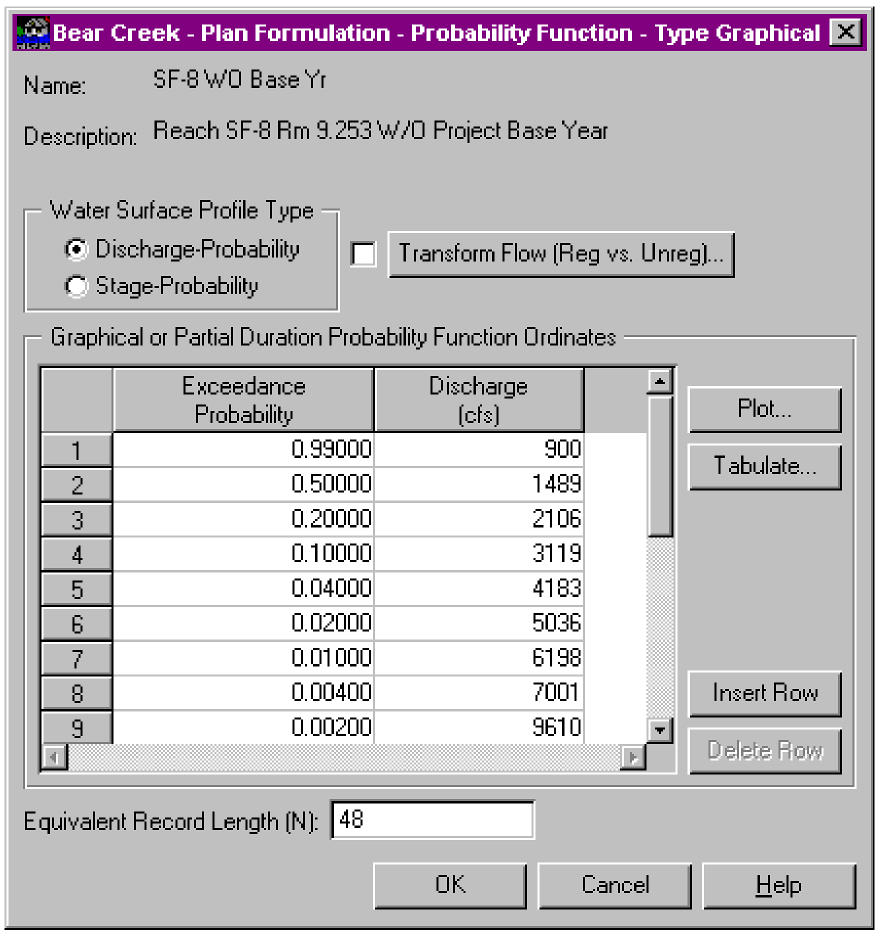


Figure 5.8 Graphical Discharge-Exceedance Probability Screen

A graphical probability function (discharge- or stage-probability) is defined by specifying the discharge- or stage-probability ordinates and the equivalent record length that describe the known function. Once specified, ordered events are interpolated from the function based on the equivalent record length and error limit curves determined using order statistics. The final graphical discharge- or stage-probability function is based on mean or expected values defined by Weibull plotting positions along the curve. The distribution of errors is assumed to be normal about the specified function. You may plot or tabulate the function and error limit curves (See ETL 110-2-537).

A flow transfer relationship may be used to define a relationship between unregulated and regulated flow, inflow and outflow, or another relationship to transform the flow defined by the discharge- or stage-probability function. This transform flow relationship could be the result of reservoir or channel routing, channel diversion, etc. It specifically allows for the isolation of the uncertainty related to the transforming mechanism, while maintaining the uncertainty of the discharge-probability function. The relationship is entered as x-y paired data. Uncertainty of the dependent variable (regulated flow) is also defined. The distribution type and the distribution parameters are entered for each point on the flow transfer function.

A transform flow function may describe the unregulated inflow into a reservoir and the regulated outflow via routing, and outlet works and/or spillway releases. The uncertainty of this function could be derived from a sensitivity analysis of the reservoir routing, varying such parameters as the outlet works and spillway ratings, outlet works operation, shape of the inflow hydrograph, assumed initial release time, political influences, safety issues, etc. Given the variety of parameters that have an impact on the outflow, one might conclude that the uncertainty distribution for this situation is asymmetric and diminishes in probability at the extremes. The triangular distribution of uncertainty, therefore, may be the most appropriate descriptor of this function. Figure 5.9 shows the Transform Flow Data Entry Screen with no uncertainty defined. Figure 5.10 shows the Transform Flow Data Entry Screen with the uncertainty defined by an asymmetic triangular distribution.

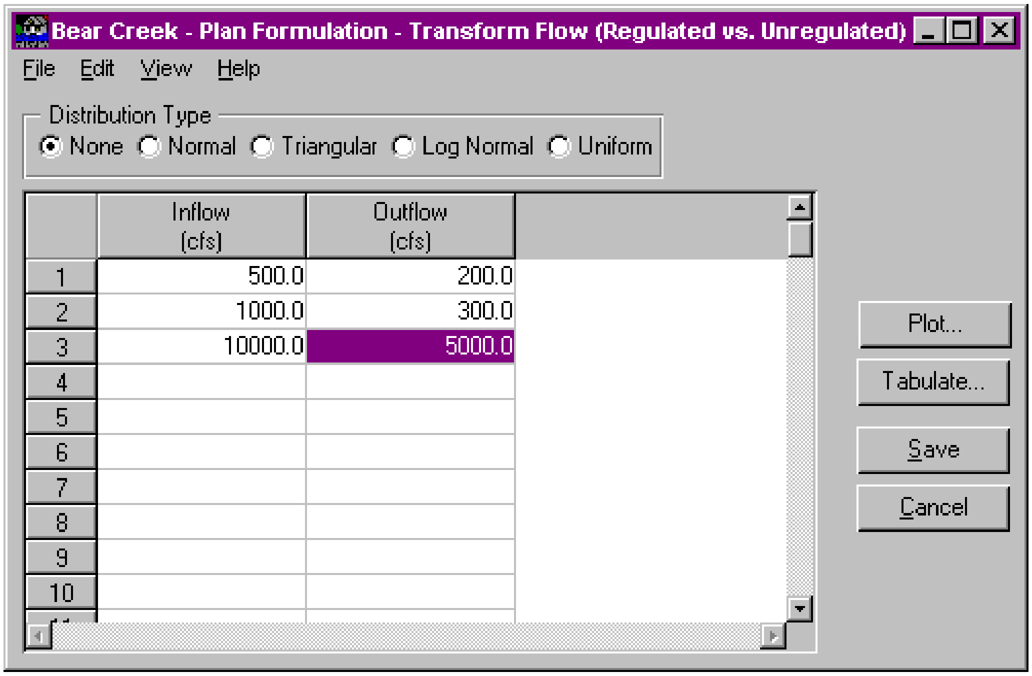


Figure 5.9 Transform Flow Data Entry Screen

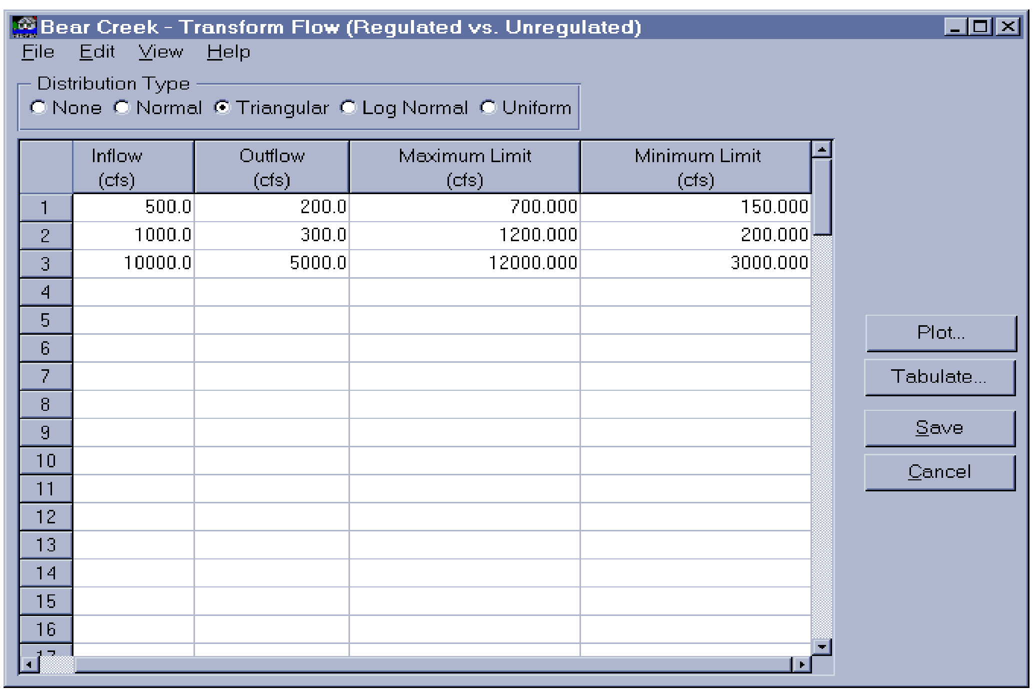


Figure 5.10 Transform Flow Data Entry Screen with Triangular Distribution of Uncertainty

When entering data in the HEC-FDA program to define graphical exceedance-probability functions, a number of data points should be used to describe the full range of the function. The uncertainty of these functions is computed using a statistical method called ordered events (Morgan and Henrion, 1990). The method determines standard errors of points (estimates) along the curve from the relationship of each of the estimates to adjacent points and the slope of the function. The number and distribution of the points effect the uncertainty computation results.

The graphical exceedance-probability functions are defined first by importing the discharge-exceedance-probability data points from the water surface profile data for the eight events and secondly, by doing the same but adding an additional point at the 0.999 (1-year) event. Figures 5.11 and 5.12 show the results for the exceedance probability function defined entirely by the water surface profile data only.

Note from the plot on Figure 5.12 that the program does not extrapolate beyond the limits of the data, in this case below the 0.5 exceedance or the 2-year event. Note also, from Figure 5.11, the range of values for the 0.01 exceedance probability event between plus and minus two standard errors is 3,150 to 12,372 cfs.

The statistics, including the uncertainty of the graphical exceedance-probability function, are influenced by the entire sample. Consequently the entire range of the function should be defined including an annual return 1-year event (0.999) estimated value.

Figure 5.13 shows the graphical exceedance-probability function and error limit values after adding an additional discharge of 894 cfs for the 0.999 or 1-year event to help define the lower end of the function. Note the range of values for the 0.01 exceedance probability event between plus and minus two standard errors is now 3,534 to 10,870 cfs. The example shows that simply adding an additional point on the frequency curve decreases the computed uncertainty substantially. This is because the program assumes nothing is known beyond the most frequent event entered (the 2-year event in the first case). Providing additional information throughout the entire sample, decreases the uncertainty. The expected annual damage would change even though it can be assumed that the 0.01 exceedance probability event is well within banks at the reach index location.

Exceedance Probability Function Report

File Help

Bear Creek - Plan Formulation

Discharge-Probability Function Report for SF-8 WO Base Yr
(Graphical)

Exceedance Probability	Discharge (cfs)	Confidence Limit Curves (standard error) Discharge (cfs) -2 SD	-1 SD	+1 SD	+2 SD
0.9990	1,478	1,476	1,477	1,479	1,480
0.9900	1,481	1,479	1,480	1,482	1,483
0.9500	1,483	1,481	1,482	1,484	1,485
0.9000	1,484	1,483	1,484	1,485	1,486
0.8000	1,486	1,485	1,485	1,487	1,487
0.7000	1,487	1,486	1,486	1,488	1,488
0.5000	1,489	1,379	1,433	1,547	1,608
0.3000	1,848	1,565	1,701	2,008	2,182
0.2000	2,106	1,611	1,842	2,408	2,753
0.1000	3,119	2,131	2,578	3,773	4,564
0.0400	4,183	2,524	3,249	5,385	6,933
0.0200	5,036	2,788	3,747	6,768	9,097
0.0100	6,198	3,105	4,387	8,757	12,372
0.0040	7,001	3,304	4,809	10,192	14,836
0.0020	9,610	3,871	6,099	15,142	23,857

Figure 5.11 Exceedance-Probability Function from Water Surface Profiles Nine Data

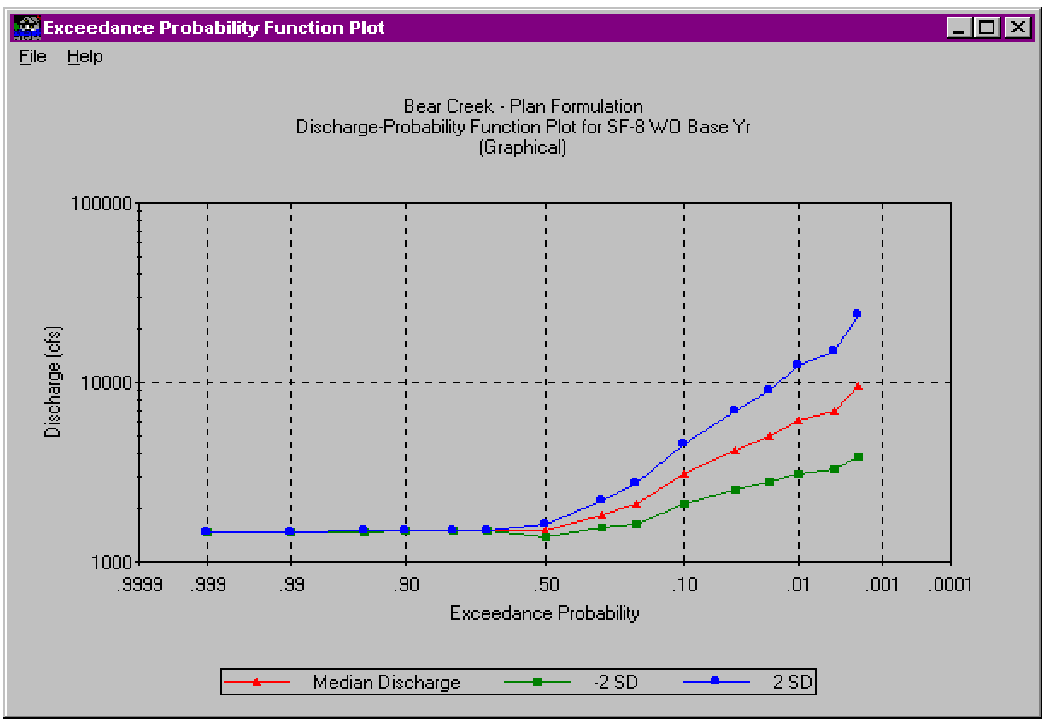
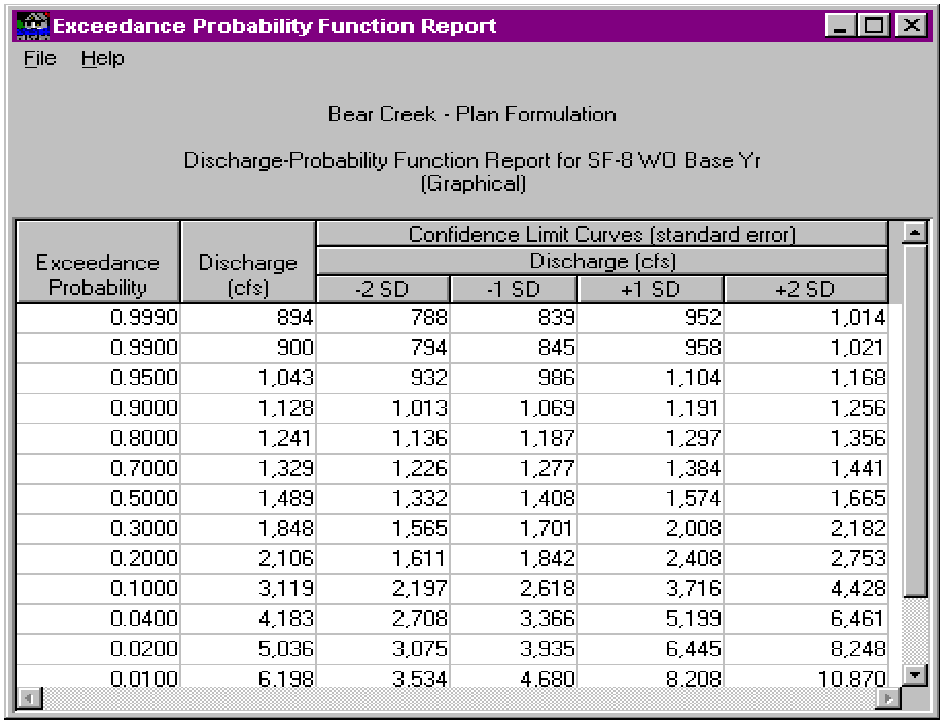


Figure 5.12 Plot of Exceedance-Probability Function from Water Surface Profile Nine Data Points



Exceedance Probability Function Report

File Help

Bear Creek - Plan Formulation

Discharge-Probability Function Report for SF-8 WO Base Yr
(Graphical)

Exceedance Probability	Discharge (cfs)	Confidence Limit Curves (standard error) Discharge (cfs)			
		-2 SD	-1 SD	+1 SD	+2 SD
0.9990	894	788	839	952	1,014
0.9900	900	794	845	958	1,021
0.9500	1,043	932	986	1,104	1,168
0.9000	1,128	1,013	1,069	1,191	1,256
0.8000	1,241	1,136	1,187	1,297	1,356
0.7000	1,329	1,226	1,277	1,384	1,441
0.5000	1,489	1,332	1,408	1,574	1,665
0.3000	1,848	1,565	1,701	2,008	2,182
0.2000	2,106	1,611	1,842	2,408	2,753
0.1000	3,119	2,197	2,618	3,716	4,428
0.0400	4,183	2,708	3,366	5,199	6,461
0.0200	5,036	3,075	3,935	6,445	8,248
0.0100	6,198	3,534	4,680	8,208	10,870

Figure 5.13. Exceedance-Probability Function Defined Over Entire Probability Scale

The HEC-FDA program does extrapolate beyond the least frequent event entered if that event is more frequent than the 0.002 exceedance probability (500-year) event. However, it is important to provide data to the 0.002 or greater event to ensure as much accuracy as possible.

Note: It is recommended that graphical frequency functions be defined between the 1- and 0.001-exceedance probability events.

Enter Graphical Discharge (or Stage)-Exceedance Probability Function

- # Select Water Surface Profile Type as discharge-exceedance probability or stage-probability, as shown on Figure 5.8.

- # You may perform analysis using the Transform Flow method by pressing the associated box and then entering the regulated vs. unregulated relationship as shown in Figure 5.9.

- # You can insert additional exceedance probability values by pressing either the adjacent left gray box or the Insert Row button.

- Enter the Equivalent Record Length (N) for the data.

- You may tabulate results and view them graphically.

Data Entry Variables for Exceedance Probability Functions

Plan Name: Select a previously defined plan name.

Stream Name: Select a previously defined stream name.

Analysis Year: Select a previously defined analysis year.

Damage Reach: Select a previously defined damage reach.

Probability Function Name: Name for the defined probability function, which is used for subsequent data entry pick lists, and labeling reports and plots. A new probability function can be added to the database. An existing probability function can be copied, updated, or deleted. The maximum length is 16 characters.

Probability Function Description: Description of the defined probability function, maximum length is 64 characters.

Probability Function Statistics: Reports the statistics entered or computed for a probability function. For the Log Pearson Type III distribution, the statistical parameters are mean (first moment), standard deviation (second moment), skew (third moment), and equivalent record length. For synthetic or parameter fitting (Compute Synthetic Statistics), the computated statistical parameters are mean, standard deviation, skew, and equivalent record length. Also, the discharge is computed. The statistic reported for a non-analytical probability function is the equivalent record length.

Analytical Discharge-Probability Function: A discharge-probability function that is fit with an analytical (statistical) distribution. The distribution is defined by statistics which are the mean, standard deviation, and skew for the Log Pearson Type III distribution, and the equivalent record length. The function is developed by site specific, hydrologic engineering analysis procedures. A "synthetic" approach defined by discharges associated with the .50, .10, and .01 probability events that fit the Log Pearson Type III distribution through the three points, may also be used.

Graphical Discharge- or Stage-Probability Function: A graphical probability function (discharge- or stage-probability) is a non-analytical function that is drawn graphically by an eye-fit curve. This means that the function is not fitted by an analytical distribution. For HEC-FDA, graphical functions should use Weibull's plotting positions (not median) because the normal distribution is used in the order statistics approach to define the error bands.

Exceedance Probability Event: The probability that a specific event will be exceeded in any given year. For example, the .01 exceedance probability event has a .01 probability of occurring in any given year.

Confidence Limit Curves: Error limit curves about an analytical discharge-probability function developed using the non-central t distribution. Confidence limit curves are used to define the discharge-probability function's uncertainty.

Stage: The vertical distance in feet (meters) above or below a local or national datum (N.G.V.D. for elevations).

Discharge (Q): The volume of water passing a specific point for a given time interval. For example, 2,000 cubic feet per second or 1,000 cubic meters per second.

Log Pearson Type III Statistics: A statistical distribution that defines an analytical discharge-probability function. The distribution has statistical parameters that define the moments of the data about the analytical curve. These statistical parameters are mean (first moment), standard deviation (second moment), and skew (third moment). Also, there is an additional parameter specified, equivalent record length.

Mean: The average value of a set of numbers, such as the annual peak discharges that have occurred over a period of time The first moment statistic of a Log Pearson Type III distribution, representing the average of the logarithms of peak discharge values.

Compute Synthetic Statistics: Log Pearson Type III statistics are computed based on the discharges associated with the .50, .10, and .01 exceedance probability events of an adopted probability function. The synthetic statistics are based on equations given in Guidelines for Determining Flood Flow Frequency, Bulletin 17B, USGS, September 1981.

Stage-Discharge Functions with Uncertainty

The stage-discharge (rating) function with uncertainty is specified for a given Plan, Analysis Year, Stream, and Damage Reach in the evaluation of flood damage reduction measures. Stage-discharge functions are required unless a stage-exceedance probability function is used.

Figure 5.14 shows the stage-discharge function data entry screen. The same median stage-discharge functions may be used for several plans and analysis years but not different streams or damage reaches. If water surface profiles are defined for the specified damage reach, the invert stage and eight point stage-discharge function at the damage reach index location may be retrieved from the water surface profile data after the plan, analysis year, stream, and damage reach are defined. See Figure 5.15.

You may specify an uncertainty (probability density function) type as either none (no uncertainty), normal, triangular, or log normal uniform. You may then manually enter the uncertainty by each ordinate or specify “calculate” to define the uncertainty for a specific stage. For this case, the error is proportioned to the invert stage for zero discharge and error. Error values above the specified stage are assumed constant (equal to the error for the specified stage). You may tabulate and plot the stage-discharge uncertainty functions.

A single stage-discharge function may be copy to another plan by clicking the **Use An Existing Function** button. The stage-discharge functions of one plan may be copied to another plan using the **Global Assignment Copy** found under **HydEng/Edit**.

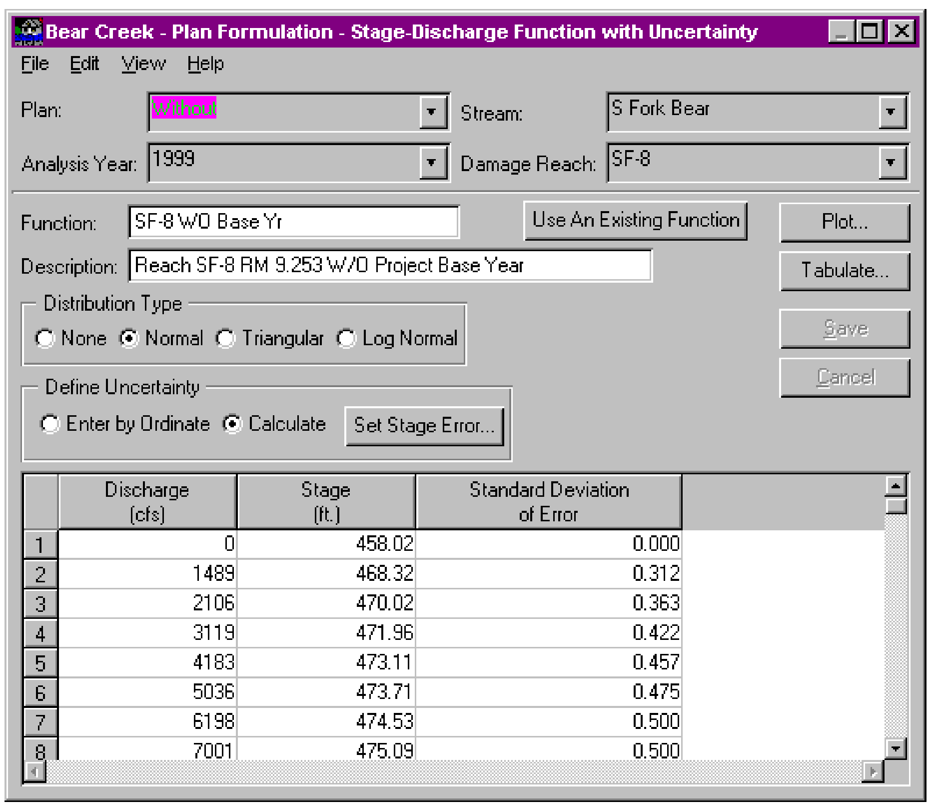


Figure 5.14 Stage-discharge Function Data Entry Screen

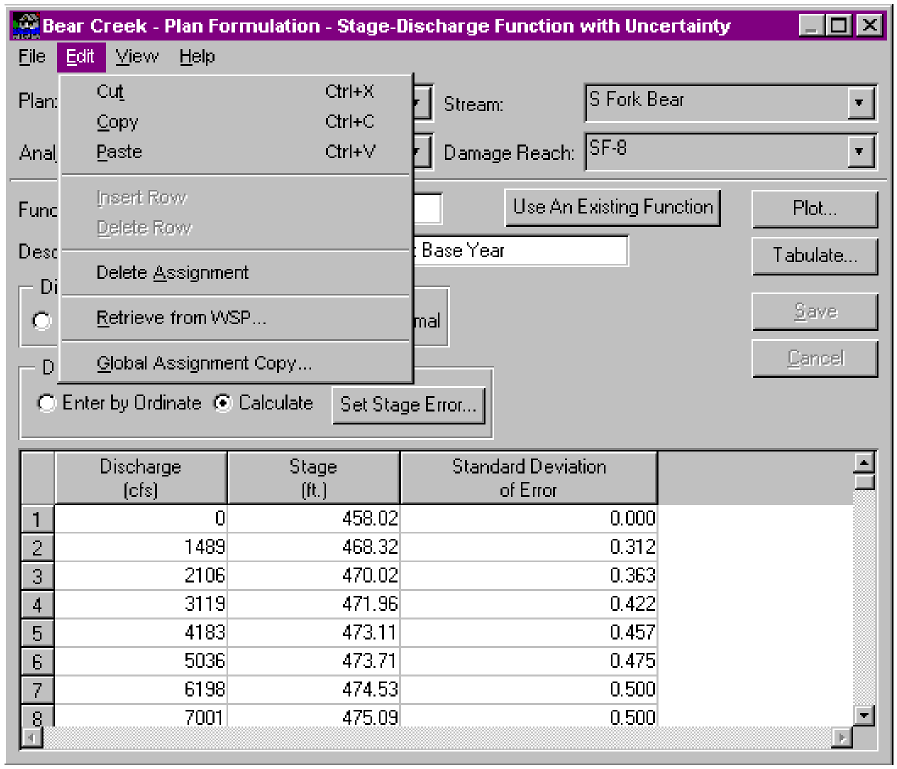


Figure 5.15 Menu for Retrieving Rating from Profiles

Data Entry for Stage-Discharge Function

Specify (assign) previously defined Plan, Analysis Year, Stream, and Damage Reach associated with this stage-discharge function.

HINTS:

- # You may review function assignments under **VIEW**.

- # You may specify uncertainty distribution type and enter stage-discharge uncertainty directly by ordinate or **Calculate** uncertainty from setting the target stage error to proportionally scale the ordinate errors.

- # You may add/delete ordinates from the **Edit** menu or by clicking the gray boxes to the left of the discharge table.

- # The highest stage value must extend beyond the highest stage affected by any flood damage reduction measure. We recommend including an ordinate to the .002 or .001 exceedance probability level.

- You may retrieve the stage-discharge function for the Plan, Analysis Year, Stream, and Damage Reach index stream station from the associated water surface profile data set. There are nine ordinates including the invert stage (zero discharge) and the eight stage-discharge values of the profiles. You may edit the values after retrieving from the water surface profiles but should assure that rating data remains consistent with the profiles.

Menu Items for Stage-Discharge Functions

Please see the Menu Item section in Chapter 3.

Data Entry Variables for Stage-Discharge Functions

Plan Name: Select a previously defined plan name.

Stream Name: Select a previously defined stream name.

Analysis Year: Select a previously defined analysis year.

Damage Reach: Select a previously defined damage reach.

Stage-Discharge Function Name: Name for the defined stage-discharge function, which is used for subsequent data entry pick lists and used on reports and plots. A new stage-discharge function can be added to the database. An existing stage-discharge function can be copied, updated, or deleted. The maximum length is 16 characters.

Stage-Discharge Function Description: Description of the defined stage-discharge function, up to 64 characters.

Normal Distribution: A two-parameter probability distribution defined by the mean and standard deviation. A symmetrical "bell shaped" curve applicable to many kinds of data sets where values are equally likely to be greater than or less than the mean. Also called a Gaussian distribution. The distribution is truncated at three standard deviations.

Triangular Distribution: A three-parameter bounded probability distribution defined by the minimum, most likely (mode), and maximum.

Log Normal Distribution: A two-parameter probability distribution defined by the mean and standard deviation. A non-symmetrical distribution applicable to many kinds of data sets where the majority (more than half) of values are less than the mean but values greater than the mean can be extreme, such as with streamflow data. The distribution is truncated at three standard deviations.

Discharge (Q): The volume of water passing a specific point for a given time interval. For example, 2,000 cubic feet per second or 1,000 cubic meters per second.

Stage: The vertical distance in feet (meters) above or below a local or national datum (N.V.G.D. for elevations).

Levee Features

Under **Levee Features**, you specify levee size and failure characteristics, interior versus exterior stage relationships associated with the levee, or wave overtopping criteria. The levee, floodwall, or tidal barrier characteristics are entered and other relationships are defined depending on whether the levee is subject to geotechnical failure or wave action (overtopping) which may cause flooding. A levee or floodwall is defined by selecting the appropriate Plan, Year, Stream and Reach in the **Levee Feature** window. The stage of the top of the levee or floodwall at the damage reach index location is entered in the appropriate field (Figure 5.16)

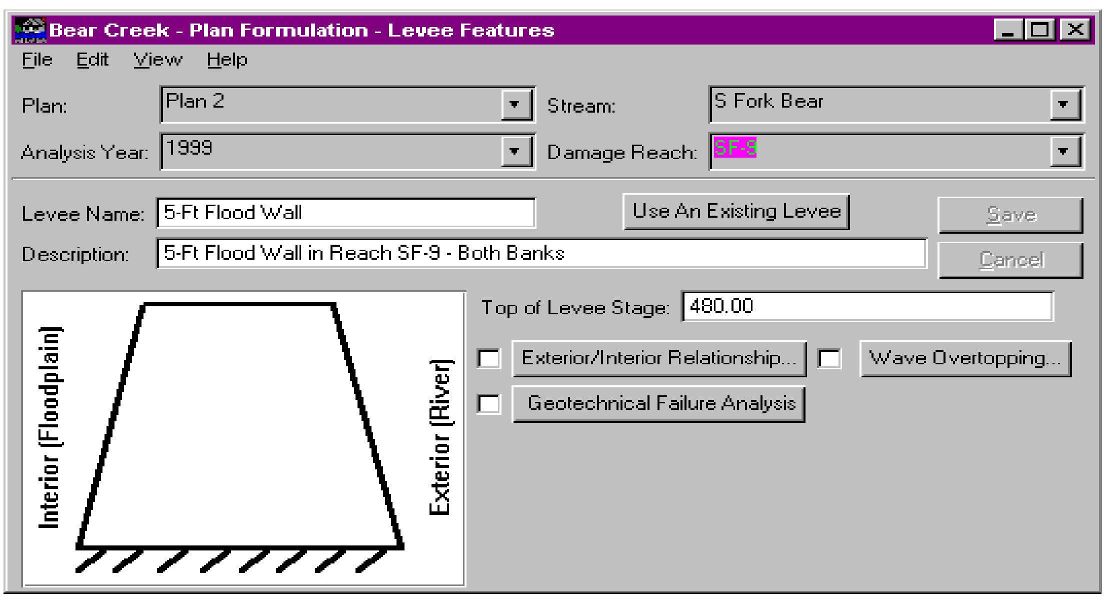


Figure 5.16 Levee Data Entry Screen

As can be seen on the **Levee Features** window (Figure 5.16), other data that describe the characteristics of levees and floodwalls and how they affect flooding can be specified.

Exterior-Interior Relationship

The exterior-interior relationship feature defines a relationship between the stage on the river or exterior side of the levee vs. the stage in the flood plain or interior side of the levee. This relationship is necessary if water that overtops the levee from the river side will not reach the same level as the top of the levee in the flood plain. This may be due to floods that result in stages near the top of the levee overtopping in a safe, controlled manner, as designed or flood hydrograph volume is not sufficient to fill the flood plain to the stage equal to the top of the levee. In either case, the relationship must be developed from hydrologic or hydraulic analyses external to the HEC-FDA program. If the relationship is not specified, the assumption is that the flood plain fills to the stage in the river (represented by the exterior stage-discharge function for the reach) for all events that result in stages that cause levee failure or are above the top-of-levee. Figure 5.17 shows the data entry screen for the levee/flood wall exterior vs. interior stage relationship.

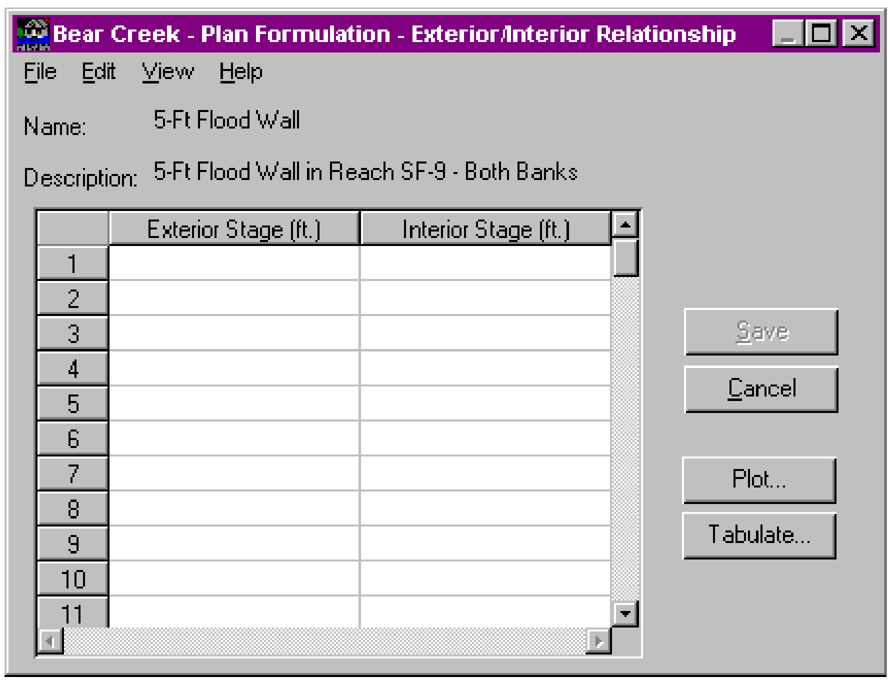


Figure 5.17 Interior vs. Exterior Relationship Data Entry Screen

Geotechnical Failure Analysis

A relationship between water surface stage on the river or exterior side of the levee vs. the probability of levee failure may be specified. This feature is used for existing non-federal levees or older levees that may have deteriorated and can no longer be assumed to hold water to the stage initially intended. The relationships are developed from geotechnical analysis according to existing geotechnical guidance. Figure 5.18 shows the geotechnical failure analysis data entry screen.

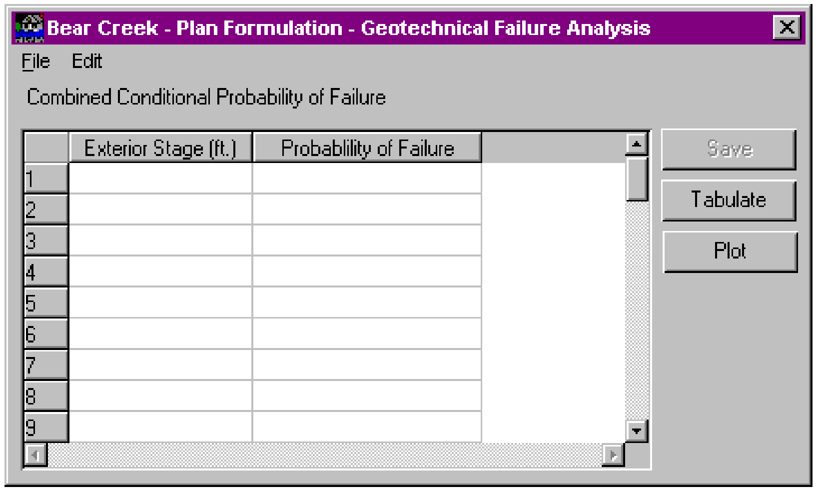


Figure 5.18 Geotechnical Failure Analysis Data Entry Screen

Wave Overtopping

Wave Overtopping Analysis accounts for effects of wave overtopping when analyzing levees, floodwalls or tidal barriers. A wave height versus still water stage relationship is specified. Still water stage corresponds to the exterior stage-discharge or stage-frequency function specified for the reach. The uncertainty of wave height is defined by specifying one of several error distribution types. When a levee or floodwall is subjected to wave action, a portion of the wave may overtop depending on whether the wave strikes the structure. The volume of water that spills over the levee or floodwall is dependent on the effective overtopping height. Wave overtopping relationships may be used to account for these factors. A relationship between effective overtopping height and resulting interior stages can also be specified. These relationships are developed outside the HEC-FDA program using wave overtoping analyses and overtopping volume versus interior stage characteristics. Appendix D describes the concepts and illustrates the wave overtopping data entry requirements in detail.

Data Entry for Levee Features

Plan Name: Select a previously defined plan name.

Stream Name: Select a previously defined stream name.

Analysis Year: Select a previously defined analysis year.

Damage Reach: Select a previously defined damage reach.

Levee Name: Name for the levee/floodwall for this plan, analysis year, stream, and damage reach. Used for subsequent pick lists and reports. A new levee can be added to the database. An existing levee can be copied, updated, or deleted. The maximum length is 16 characters.

Levee Description: Description of the defined levee. The maximum length is 64 characters.

Top of Levee Stage: The stage (elevation) of the top of the levee at the damage reach index location.

Exterior Stage: The stream-side stage associated with water surface stages, profiles at the damage reach index location. Used to define relationships of interior stages and levee failure probabilities.

Interior Stage: The interior stage associated with the exterior stage that is required when the levee overtops, but not enough flood volume is available to equalize the interior stage with the exterior stage. A detailed hydraulics analysis outside of HEC-FDA is required to determine the exterior-interior relationship. The corresponding interior stage values are used for the damage computations of the interior area.

Probability of Failure: The probability of the levee failing geotechnically for a given exterior stage. The relationships require detailed analyses outside of HEC-FDA. Failure is assumed the combined conditional probability of failure from such causes as: piping, seepage, and underseepage.

Still Water Stage: The stage corresponding to the exterior stage-discharge or stage-frequency function at the damage reach index location. Still water stage is associated with the wave height to determine wave overtopping conditions and analyses.

Wave Height: Wave height is in feet (meters) and is associated with the still water stage.

Wave Shape Factor: The ratio of the portion of the wave above the levee or floodwall to the total wave height. It is determined by dividing the total height by the wave runup. The total height above the levee is determined by subtracting the levee crest stage from the exterior stage with wave. The wave runup is assumed equal to two-thirds the wave height if the still water stage alone exceeds to top-of-levee or to the full wave height if the still water stage is below the top of the levee.